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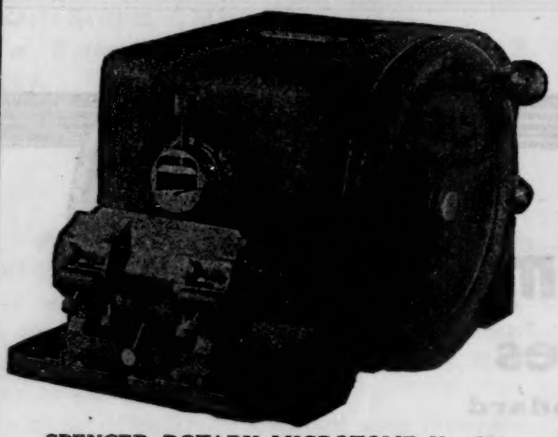

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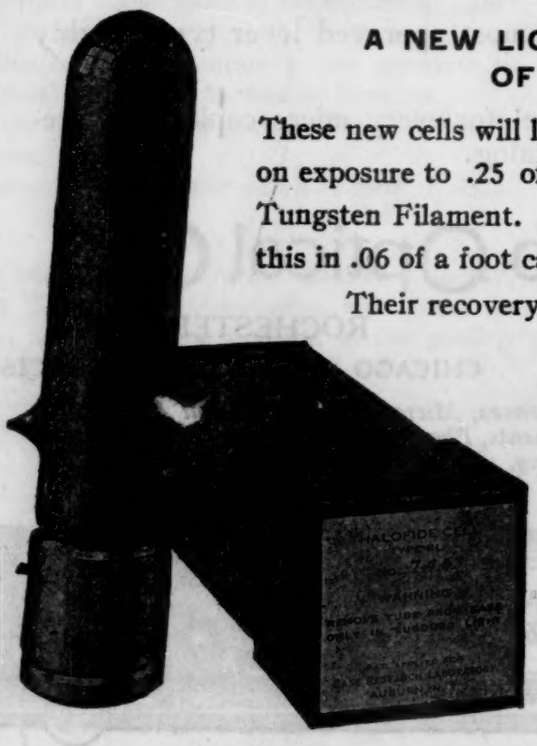

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LOCAL ANESTHETICS[1]

SINCE earliest times, those who have resorted to surgery for the relief of their fellow creatures, have desired to mitigate their procedures by the exclusion of pain. Generally speaking, this has been brought about by a complete abolition of consciousness, whence the term *anesthesia* ("without sensation").

To those cases in which sensation is removed by the application of a drug only at the point of operation is applied the term *local anesthesia;* substances used for this purpose are termed local anesthetics. Some authorities consider this designation inaccurate because during the employment of these substances consciousness is fully retained. They might therefore be described as local *analgesics* ("without pain") but the other term has the sanction of usage.

Historians cite abundant instances of the employment in ancient times of general anesthesia, the oldest being a case of removal of a rib. For this purpose we are told that "the Lord God caused a deep sleep to fall upon Adam," the patient. The commonest of the age-old general anesthetics are alcohol opiates and mandragora, all of which were given separately or mingled with other ingredients.

Local anesthesia, on the other hand, was attempted with comparative infrequency before the last century. Perhaps the earliest authentic description of an approach to this method is that which emanates from the school of Salerno,[2] in the twelfth century. In those days was practised a form of general anesthesia by causing the patient to inhale the vapors of so-called "soporific sponges," the chief ingredients of these being poppy, hen-

[1] Lecture given before the Brooklyn Institute of Arts and Sciences, February 7, 1920.

[2] Cited by Husemann, *Deutsch. Zeitschr. f. Chirurgie,* 1896, 42, 585.

bane and mandragora. As moist poultices the same substances were sometimes laid upon the area where cutting, burning, or some other surgical procedure was to be done. We are told that sensation was thus removed and no pain experienced, but the instance must be assigned with great caution to the category of local anesthesia. The abolition of pain may have resulted only after absorption of these drugs into the circulation, by which means if carried to the brain in sufficient quantity they would, by their central action, produce general stupefaction. From what we know of the action of these substances the remote rather than the local action would be expected. From among such old-time local applications there has come down to us "lead and opium wash," but modern pharmacologists are most skeptical as to the efficiency of opium applied externally.

Prior to the school of Salerno, it is known, of course, that oils and salves were frequently applied to wounds and other painful areas. For example Dioscorides refers to the employment as an eye lotion, of rose oil, a substance about which we shall have more to say later. Of the use of local applications during actual surgical procedure in those days I am aware of no direct evidence.

Many writers refer to the Memphis Stone, of which the oldest descriptions are those of Dioscorides and of Pliny, neither of whom apparently saw it used. Husemann cites conflicting descriptions of its mineralogy. It was called blunt, thick, the size of a pebble; a soft black and hard white variety were applied to the forehead to relieve headache, while an ash-gray variety was said to be of value for snake bites. This talisman and panacea according to both Dioscorides and Pliny was of Egyptian origin and was used to produce local anesthesia, for which purpose it was sometimes powdered and mixed with vinegar. In view of the fact that it was described as a variety of marble the untenable hypothesis has been suggested that the local anesthetic effect was the result of the evolution of carbon dioxide from this mixture when applied to the area of operation.

A second local anesthetic of Egyptian origin and referred to in the sixteenth century by a Dutch physician, Ronsseus, was crocodile fat. In a Latin poem, "Venatio Medica," this author tells us that crocodile fat and a salve of oil and burnt lizard skin were efficient as local anesthetics if applied before cutting or burning.

In the seventeenth century, we are informed of the use of another method of producing local anesthesia, namely the application of cold (for example, by ice and salt mixtures). This was practised by Thomas Bartholinus, who learned it apparently from a distinguished Danish physician, Marc Aurelio Severino. Modern developments of this include the employment of ethyl chloride and other substances of very low boiling point to freeze the skin for minor operations.

The story of modern local anesthetics begins with the isolation in 1860, by Niemann in the laboratory of the German chemist, Wöhler,[3] of the alkaloid cocaine. From Lima, had been brought the leaves of *erythroxylon coca,* a plant which had for years attracted the attention of travelers in Peru and Bolivia on account of its widespread use by the natives as a stimulant. The plant, native to the slopes of the Andes, is a shrub attaining a height of about six feet, with bright green leaves, similar in size and shape to those of tea, which are rapidly replaced when picked. The annual consumption of these leaves in South America is now estimated at one hundred million pounds.

The "coqueros" or chewers of coca leaves had ascribed wonderful properties to them, not only of abolishing hunger, fatigue, bodily discomfort, etc., but also of psychic stimulation of various sorts. When put to the test in Europe these claims were but poorly substantiated owing, according to some, to deterioration of the properties of the leaves in transportation, but probably more to a difference in the subjective conditions of the test; that is, the European investigators were probably neither as hungry and fatigued nor con-

[3] Wöhler, F. W., *Ann. der Chem. u. Pharm.*, 1860, 114, p. 213.

stitutionally as emotional as the "coqueros." Nevertheless sufficient nervous stimulation is derived to render cocaine a dangerous habit-forming drug.

After the manner of chemists with a new product, Wöhler tasted cocaine and noted (to translate literally), that "it is bitter and exerts upon the tongue nerves a characteristic effect in that the point touched becomes temporarily numb, almost without sensation." Twenty-four years elapsed before the significance of this finding was fully appreciated; Koller, a Viennese oculist, in 1884 introducing it as a practical local anesthetic for the eye. In the meantime, however, Parisian workers had noted anesthesia of the tongue when the leaves were chewed with alkali (DeMarle, 1862); and Moréno y Maiz (1868), had suggested the employment of the drug as a local anesthetic. A number of fundamental pharmacological facts about cocaine were demonstrated by Von Anrep[4] (1880).

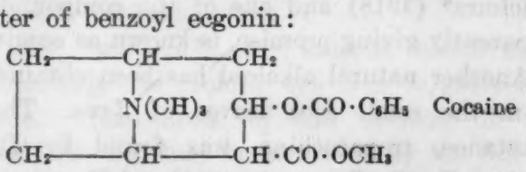
From the eye clinic the use of the drug spread to laryngology and rhinology and later to general surgery. As it is typical of a large class of local anesthetics its action may now be somewhat more fully detailed.

Cocaine is classed as a "general protoplasm poison," since relatively small amounts exhibit the power to interrupt or suppress the life process both of lower and higher organisms. In mammals it attacks nerve tissue in particular and there are acute and chronic types of brain poisoning, the latter, of course, being illustrated in the widespread abuse of the drug. Acute poisoning (motor excitement and high temperature followed by convulsions) has been noted in all attempts at anesthetization of animals by intravenous injection or other means of introducing the drug into the general circulation. The local or peripheral action can not be obtained by such methods.

The portions of the nervous system upon which the action is useful are the nerve trunks and their sensory endings, and as may be judged from the above, one problem of the surgeon is to keep the substance limited as far as possible to these regions. On the nerve trunks it has a selective action in blocking afferent or sensory impulses much more readily than efferent or motor impulses, both of which are carried by the same bundle of nerve fibrils. Its selective action is further illustrated by the abolition, upon application to the nerve ends, of pain and touch sensations, while the perception of heat and cold remains uninterrupted. Again, on the tongue, in addition to touch and pain, the perception of "bitter" taste is completely eliminated, yet those sensations which we describe as "sweet" and "acid" taste are still dimly perceived, while the presence of salt may still be appreciated as well as ever.

That cocaine is not an ideal local anesthetic can be readily appreciated. Aside from its disadvantages as a habit-forming drug and the possibility of the development of toxic symptoms if unskillfully employed, there are minor objections which include the possibility of injury to the tissues or interferences with natural processes of repair if given in too concentrated a solution and the fact that solutions if sterilized by boiling undergo some decomposition.

Since these facts began to receive attention the production and testing of synthetic substitutes for cocaine has been a nearly continuous performance. As the structural formula of the alkaloid shows, it is the methyl ester of benzoyl ecgonin:

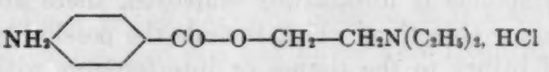


Its decomposition products are methyl alcohol, benzoic acid and the tropine-like base ecgonine. Investigations by Filehne, Paul Ehrlich, and others, were undertaken to determine in which of these chemical groups or in what combination of radicals the anesthetic virtues resided. The benzoic acid radical was soon indicated as being of importance; for example, neither ecgonin nor methyl ecgonin were found at all like cocaine in their action. On the other hand the isomer of cocaine in which the methyl and benzoyl radicals were

[4] Von Anrep, B., *Pflüger's Archiv. der Physiologie*, 1880, 21, 38.

made to exchange places, exhibited no local anesthetic properties; when, however, the benzoic acid radical was replaced in the cocaine structure by other homologous acids, substances with cocaine-like action were evolved.

Einhorn, who had earlier been associated with Ehrlich's work, introduced as a local anesthetic orthoform. This is the methyl ester of an oxy-benzoic acid modified by the introduction of an amino group to replace the very complicated base ecgonine. This substance, while poorly soluble, has found a place in surgery as an anesthetic dusting powder. Einhorn[5] next modified the orthoform grouping in such a way as to produce more soluble compounds, but achieved his greatest success by the introduction of the "alkamine" esters of benzoic acid, notably procaine (known also by the trade name of novocaine):



Procaine.

In other synthetic compounds (stovain, alypin, and B-eucaine), no amino group appears on the benzene nucleus. In still another series of compounds, the benzoyl group has by an intervening side-chain been attached to the nitrogen of the ecgonine molecule. This work was reported recently by Wichura[6] (1918) and one of the compounds, apparently giving promise, is known as eccain.

Another natural alkaloid has been obtained from the small coca leaves of Java. This substance, tropacocaine, was found by Dr. Arthur P. Chadbourne[7] (1892), of Boston, to possess valuable anesthetic properties. Similar in structure to cocaine (of which it is in many ways the equal) it contains pseudotropine in place of the ecgonine radical.

In the group of antipyretic drugs also are found substances of value as local anesthetics, although these are chemically quite unrelated to cocaine. Among them are holocaine, a phenacetin derivative, and quinine, which is used in combination with urea. In 1913, Morgenroth showed that certain quinoline derivatives have a similar action, including a group of substances which also give promise of a specific value in the treatment of pneumonia. Antipyrine may be included in this and in the following group.

In 1888, Liebreich[8] called attention to the fact that a large number of substances are capable of producing "anesthesia dolorosa." This term is applied to the phenomenon of smarting followed by loss of sensation. Among the substances which he enumerated were sodium bromide, ammonium chloride, lead acetate, ferric chloride, resorcin, and even the glucosides saponin and napellin. Carbolic acid affords the most conspicuous example of this type, its action culminating as is well known in the death of tissue.

In spite of the untoward effects of carbolic acid, which is an aromatic alcohol, certain closely related aromatic side-chain alcohols are now yielding much promise of practical value. Dr. David I. Macht,[9] of Baltimore, the pioneer in this field, a few years ago noted the anesthetic effect of benzyl alcohol upon the tongue, demonstrated its highly innocuous character, and was instrumental in introducing it into surgery.

In our laboratory three similar side-chain aromatic alcohols have been tested, chiefly by Dr. Axel M. Hjort,[10] whose work has been aided by the Committee on Scientific Research of the American Medical Association. As will be seen from the following summary of Dr. Hjort's findings, two of these, rose oil and benzoyl carbinol, possess a high degree of anesthetic efficiency combined with a low degree of toxicity.

[5] Einhorn, *Liebig's Annalen*, 1908, 359.

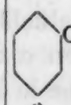
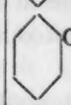
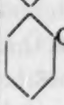
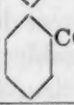
[6] Wichura, Wilhelm, *Zeits. für Exper. Path. and Therapie*, Vol. 20, p. 1.

[7] Chadbourne, A. P., *Brit. Med. Jour.*, 1892, II., 402.

[8] Liebreich, *Verhandl. de 7 Kongr. f. inn. Medizin*, 1888, S. 245.

[9] Macht, D. I., *Jour. Pharm. and Exp. Therap.*, 1918, XI., 263.

[10] Hjort, A. M., and Kaufmann, C. E., *Proc. Soc. Exp. Biol. and Med.*, January, 1920.

	Formula	Minimal Lethal Dose White Mice. Mgs.	Minimal Effective Anesthetic Concentration (Rabbits' Cornea) %	Minimal Effective Anesthetic Concentration in (Human Skin) %
Benzyl Alcohol..	 CH_2OH	50	1.25	1/30
α Phenethylol ..	 $CHOHCH_3$	20	0.75	1/40
β Phenethylol (rose oil)	 CH_2CH_2OH	40	1.00	(1/40)
Benzoyl Carbinol	 $COCH_2OH$	40	0.50	1/40

Rose oil, or β-phenethylol, it will be remembered, was one of the preparations mentioned by Dioscorides as an eye wash; roses apparently were considered effective in many diseases at that time. Blondel[11] (1889) describes the use of essence of rose for its stimulant properties, its action when taken by mouth not differing essentially from that of other volatile oils. This substance as well as its isomer α-phenethylol are liquids, the latter exhibiting greater toxicity, the probability of which we had deduced from the fact that it contains an asymmetrical carbon atom. Benzoyl carbinol is a solid at ordinary temperatures and of all the group has yielded the most promising results.

While it is more practicable to make the detailed toxicity tests upon mice, it is important to control the results by tests upon higher mammals. In dogs it was found that, like benzyl alcohol, rose oil and benzoyl carbinol fail to cause more than the most transitory symptoms when injected rapidly into the veins in doses of 200 mgms. per kilo. This contrasts very favorably with the toxicities of the commonly used local anesthetics which have been carefully determined by Drs. Robert A. Hatcher and Cary Eggleston,[12] of New York. These investigators found, for example, that by rapid intravenous injection in cats 40–45 mgms. per kilo of procaine or 15 mgms. per kilo of cocaine are fatal. Thus the benzyl alcohol and rose oil appear at least five times as safe as procaine.

The toxicity of benzoyl carbinol in comparison with a series of common local anesthetics may be illustrated graphically by the following adaption of Eggleston and Hatcher's diagram:

Fatal Dose. Mgms. per Kilo	Relative Toxicity
> 200.....	Benzoyl Carbinol, benzyl alcohol, etc.
40– 45.....	Procaine
30– 35.....	Nirvanine
25– 30.....	Stovaine
18– 22.....	Tropacocaine
20.....	Apothesine
15.....	Cocaine
10–12.5.....	Beta-Eucaine
10.....	Alypine and Holocaine

Hatcher and Eggleston point out that with local anesthetics, as with other drugs, the degree of toxicity may depend upon the rate of injection or absorption into the circulation. They show that slow injection allows time for destruction by the liver.

On the basis of the results in dogs it would appear that a man could safely tolerate the throwing of solutions containing one half ounce of pure rose oil or of benzoyl carbinol directly into the circulation; used as a locally applied anesthetic, therefore, poisoning would scarcely be anticipated.

For "surface" or "mucous membrane" anesthesia the rabbits' eye is a valuable test object. Anesthesia of the surface of the rabbit cornea may be identified by the failure of the animal to respond by a wink when the center of the eye is touched. Schlüter has published interesting experiments in which after a drop of local anesthetic was instilled into the eye the threshold for touch sensation was followed by means of hairs of different weights. He showed that when solutions of equal strength are compared, procaine is quite inferior to cocaine as a surface anesthetic. Benzoyl carbinol, as shown below, is particularly efficient in this respect, yielding complete anesthesia of the cornea in 0.5 per cent.

[11] Blondel, R. E., Thesis, "Les Produits Odorants des Rosiers," Paris, 1889.

[12] Eggelston, C., and Hatcher, R. A., *J. Pharm. and Exp. Ther.*, 1919, 13, 433.

concentration. This is the first of the aromatic side-chain alcohols to equal cocaine as a surface anesthetic.

The following diagram (adapted from Sollmann) illustrates the comparative efficiency of phenolic side-chain alcohols and the commonly used surface anesthetics:

Minimum Anesthetic Percentage	Relative Efficiency for Surface Anesthesia
0.5	Cocaine, holocaine, benzoyl carbinol
0.75.....	α-phenethylol
1.0	Beta-Eucaine, rose oil
1.25.....	Benzyl alcohol
2	Tropacocaine, alypin, quinine-urea
4	Apothesine
8	Novocaine
10	Antipyrine

The intracutaneous method of testing local anesthetics was introduced by Hoffmann and Kochmann (1914) and consists in the production of wheals resembling mosquito bites, by driving the anesthetic substance in between the layers of the epidermis, under pressure, with the hypodermic syringe. The subject of the experiment, who is, of course, prevented from watching the procedures, is required to give a signal every time he perceives the touch of a straw tipped with absorbent cotton. None of our phenolic alcohols are found irritating by this method and all destroy sensation in a concentration of about 1/40 of 1 per cent., as low a strength as has proved sufficient for any known anesthetic substance.

This is illustrated by the following diagram (also adapted from Sollmann):

Minimum Anesthetic Percentage	Relative Efficiency for Intracutaneous Anesthesia
1/40	Benzoyl carbinol, rose oil, α-phenethylol
1/30–1/32.....	Benzyl alcohol, cocaine, novocaine, tropacocaine, alypin
1/16	Beta-eucaine
1/8	Quinin-urea
1/4	Apothesine, antipyrine, K_2SO_4

Dr. Arthur D. Hirschfelder,[13] of Minneapolis, and his collaborators, have recently announced the results of experiments with similar side-chain aromatic alcohols. A number of these are based upon the salicylic acid radical. From Hirschfelder's results it is obvious that saligenin in 2 per cent solution is likely to prove a very valuable anesthetic. In his hands this has given a 28–45 minute human subcutaneous anesthesia and has completely anesthetized the mucous membranes of the eye.

Several benzyl alcohol homologues, therefore, which are more stable than benzyl alcohol itself, better surface anesthetics than procaine, and at least five times less toxic, and which further are presumably very unlikely to become habit-forming drugs, are now receiving practical trials.

The two above described tests, surface and intracutaneous, represent the most important of the procedures employed by the surgeons. Clinically, there are five main varieties of local anesthesia, namely, (1) surface, (2) terminal, (3) regional, (4) spinal, (5) venous.

1. To anesthetize mucous membranes such as the linings of the eye, nose, and throat, the solution requires only to be painted upon the surface.

2. To anesthetize the nerve ends in the skin, however, it is necessary that the drug be injected into the skin by means of the hypodermic needle. This is owing to the fortunate circumstance that the living layers of the epidermis are quite impermeable to most solutions with which they may come in contact. Obviously where deper incisions are to be made, subcutaneous injections must follow. Schleich[14] modified the method of terminal anesthesia very acceptably by showing that if hypotonic solutions be injected under pressure to the point at which the tissues become rigid, the anesthetic may be reduced in concentration. This is in accord with findings that either hypotonic or hypertonic solutions of salts tend of themselves to produce local anesthesia, apparently owing to the fact that in swelling or shrinking respectively,

[13] Hirschfelder, A. D., A. Lundholm, H. Norrgaard, American Chemical Society, Division of Biochemistry, September 4, 1919.

[14] Schleich, C. L., "Schmerzlose Operationen," Berlin, 1906.

the vital processes of the cells are partly interfered with.[15]

3. To anesthetize the area supplied by a given nerve, it is only necessary to inject a sufficient amount of solution directly into the nerve trunk. This often effects a great saving of labor and material. The larger nerve trunks were first blocked in this manner by Dr. Harvey Cushing, of Boston.

4. Anesthetics are occasionally injected under the sheath of the spinal cord itself. Spinal anesthesia was introduced in 1885 by Dr. J. Leonard Corning, of New York, in the same year in which Dr. Halsted, of Johns Hopkins, began his pioneer work in cocaine surgery. Many of you may recall that in the closing years of the last century a substance known as stovaine, belonging to the orthoform group, was widely heralded in connection with spinal anesthesia.

5. To produce venous anesthesia an area is made bloodless by tight bandaging and the anesthetic solution injected backwards into the vein which ordinarily transports blood away from that area.

Certain substances have been tested as adjuvants, to be added to local anesthetic solutions. Among these epinephrin has been found extremely valuable and is universally employed, while sodium bicarbonate and potassium salts are deserving of mention.

For terminal anesthesia procaine is injected in solution with epinephrin, the active principle of the adrenal gland. A concentration of 1–100,000 of the latter suffices to blanche the tissues by contracting the small blood vessels with which it comes in contact. This serves two useful purposes, to make the operation practically bloodless and to prevent any rapid carrying off of the drug into the circulation.

[15] Terminal used in combination with general anesthesia is believed to rob the latter of some of its disadvantages, for while the patient, narcotized by ether, chloroform, or nitrous oxid, does not perceive the afferent nerve impulses set up by surgical procedures, these reach the central nervous system nevertheless and may contribute to the untoward condition known as "shock." Local anesthesia tends to prevent the transmission of such impulses. (Crile.)

Sodium bicarbonate as an adjuvant to local anesthetics was suggested by Gros[16] (1910), who believed that bringing the alkaloids into their basic forms, would aid them in penetrating the tissues. Dr. Torald Sollmann,[17] of Cleveland, has found that it does in fact enhance the action of such alkaloids when they are applied to mucous surfaces. On the other hand, he denies that it has any special value in terminal anesthesia.

With regard to potassium salts it may be mentioned, that Hoffmann and Kochmann[18] (1912) claimed that potassium sulphate powerfully potentiates the action of procaine in intracutaneous anesthesia. Dr. Sollmann's results conflict with this claim as do also the results of a number of unpublished experiments which I have made in association with Professor Bernard E. Read, of Peking. In short, salts of potassium, which in fairly high concentration produce a certain amount of intracutaneous anesthesia, when given in combination with such a substance as procaine, yield a result representing merely the algebraic sum of the results obtained by giving the two substances separately.

The theory of action of local anesthetic drugs has not yet reached a satisfactory state. Gros believes that their anesthetic power runs parallel to the amount of free base which is present and that esters such as cocaine and procaine must therefore be hydrolyzed before anesthesia can take place. The extent of the anesthesia would therefore depend upon the degree of hydrolysis of the drug taking place in the tissues. The new findings concerning substances of the benzyl alcohol series show that phenolic alcohols contain all that is essential to local anesthetic action and that for introduction into the field of operation it is not necessary to mask them as esters.

Exactly what happens to the nerve tissues when brought into contact with a local anesthetic drug has not been determined.

[16] Gros, O., *Arch. f. exp. Pathol. u. Pharmakol.*, LXIII., 1910.

[17] Sollmann, T., *J. A. M. A.*, January 26, 1918, p. 216.

[18] Hoffmann, A., and Kochmann, K., *D. M. W.*, 1912, 38, 2264.

We can say, however, in view of the results of work initiated by Dr. A. P. Mathews, that the vital processes in nervous tissue become retarded. This is indicated by the lowered carbon dioxide production exhibited by a nerve exposed to cocaine. Niwa[19] (1918) states that "there is a close relationship between the rate of nerve metabolism and the state of excitability of the nerve" and that "anesthesia in general is probably brought about by interference with the tissue metabolism." This does not differ greatly from Verworn's theory of anesthetic action.

While practise in this case, pending the perfection of theory, proceeds with a tolerable degree of satisfaction, we still await the demonstration of the ideal local anesthetic. This form of anesthesia, however, is extending its usefulness through an ever widening field. Few are the types of major operations which can not now be successfully conducted under its sole employment, always provided that numerous external conditions are satisfied. Among the advantages ascribed to it when thoroughness of operative procedure is not thereby sacrificed are its high degree of safety and rapidity of induction, the exclusion of shock and often of after-pain, the necessity for fewer assistants, the shortening of convalescence, and the absence of post-anesthetic complications. An additional factor of importance is the better mental attitude with which many patients approach such a procedure rather than an operation involving the surrender of consciousness. Some enthusiasts go so far as to say that many an operation assumes the character of a social rather than a surgical occasion, the patient perhaps smoking throughout and enjoying a good meal directly thereafter.

While we are not so advanced that serious ceases are made thus attractive, the day of ideal surgery will doubtless be hastened by the replacement of older for better local anesthetics.

Henry G. Barbour
Department of Pharmacology,
Yale University School of Medicine

[19] Niwa, Shuichi, *Jour. Pharm. and Exp. Therap.*, 1919, 12, 323.

PHENOMENA IN THE ULTRA-VIOLET SPECTRUM, INCLUDING X-RAYS

At the recent St. Louis meeting of Section B, of the American Association for the Advancement of Science, there was held a symposium devoted to a comparative discussion of the phenomena involved in the ultra-violet "light" and "X-ray" spectra. The following abstracts of the papers have been prepared by the authors:

A. Quantum Emission Phenomena—Radiation, by David L. Webster, Massachusetts Institute of Technology.

This paper contained a review of the laws of excitation of radiation by electron impact in the best known cases in X-rays and light, in which it appeared that the most essential difference is the existence in light of the so-called "single-line spectrum" which is unknown in X-rays. The phenomena are explainable on any theory of stable electron positions, such as the Bohr theory, if we assume: (1) that in the normal atom all positions involved in X-ray production are full (Kossel), and (2) all positions above the one corresponding to the series term 1.5S are empty (Van der Bijl).

Such theories are very unsatisfactory for absorption phenomena, especially since absorption is a continuous process but results in the production of photoelectrons, each with an absorbing oscillator and a gradual accumulation up to the value required for the photoelectron. If energy is thus stored it seems probable that it would be available to help in the production of X-rays or light by impact, and to produce other effects to be expected from it. But no such evidence of it can be found. The storage hypothesis is made only because it is demanded by the law of the conservation of energy. But this law has been observed only statistically, and the best way to reconcile these phenomena of electron impact with other radiation phenomena seems to be to assume that the law holds only statistically and does not apply to every oscillator at every instant.

B. Quantum Emission Phenomena-Electrons, by R. A. MILLIKAN, University of Chicago.

Experiments on the potentials necessary to apply to just prevent the escape of photo-electrons from different metals, combined with measurements on the contact E.M.F.'s between the same metals demonstrate, not that the energy *absorbed* by an electron which is being photoelectrically ejected is $h\nu$, but rather that the *kinetic energy* with which the electron *escapes* from the atom under the influence of incident radiation of frequency ν is $h\nu$, and hence that *the absorbed energy must always exceed $h\nu$ by the amount of the work necessary to detach the electron from the atom.* In other words the absorption of energy can not take place *quantum-wise* at all

The energy which must be absorbed to cause the escape of an electron must always be more than a quantum and may exceed that amount by any fractional part thereof. It is only the kinetic energy of the escaping electron which is always an exact quantum.

The emission of electromagnetic radiation may or may not take place quantum-wise. Characteristic or fluorescent radiation appears to be emitted quantum-wise but scattered radiation is not so emitted.

C. Spectrum Series, by WILLIAM DUANE, Harvard University.

There is presented for discussion the following four topics: (*a*) The combination law applied to the series spectra of ordinary light, and a somewhat similar law for characteristic X-rays; (*b*) the meaning of these laws in terms of the energy of the radiating atom from the point of view of the theory of radiation in quanta; (*c*) the law of constant angular momentum as used by Bohr in explaining some of the details of series spectra; (*d*) Bohr's theory applied to characteristic X-rays, with special reference to critical absorption data.

(*a*) It has been found empirically that the frequencies of vibration (or the wave numbers) corresponding to the lines in series spectra may be represented as the differences between any two of a set of terms, which may be denoted by symbols of the forms $(1S)$, $(1P)$, (mP), (mD), (mF), $(1s)$, (mf), etc. These terms may approximate to, but do not exactly equal a certain constant divided by the square of a whole number. The differences between the correct values of various pairs of terms, however, appear to represent the wave numbers with great precision.

Turning to X-rays we find that the form of the "terms" is much more complicated. It is possible, however, to obtain empirically a relation between the X-ray emission and absorption frequencies that resembles the above combination law. Mr. Shimizu and I recently published[1] the results of experiments, which indicate that an emission frequency equals the difference between two absorption frequencies. From the data for the K and L series of tungsten, it appears that the law is correct to about one fifteenth of a per cent. Since we presented this research to the Physical Society some measurements by Dr. Stenstrom of the absorption frequencies in the M series of uranium and thorium have come to hand, and these together with de Broglies' values for the L absorption frequencies and Seigbahn's values for the L emission frequencies furnish data by which the law can be tested. The calculations indicate that the differences between the L and M absorption frequencies equal the frequencies of some of the L emission lines to within one per cent.

Theories of the mechanism of radiation such as that suggested by Bohr lead to laws similar to the combination law, and Kossel has deduced from these conceptions relations between the emission frequencies themselves. One of these relations is that the difference between the Kβ and the Kα frequency equals the Lα frequency. This relation is not exact, however, for Kα represents a group of lines and recent experiments have shown that Kβ also is not a single line. We get a much closer agreement, if we take the frequencies of the individual lines in the groups.

(*b*) For a long time spectrum analysis remained a purely descriptive science, containing data of extraordinary accuracy, it is true,

[1] *Physical Review,* July, 1919.

but of very little fundamental significance. Recently, however, this data has furnished evidence of great importance as to the structure of matter and the mechanism of radiation. This is largely due to two fundamental laws: Planck's law of radiation in quanta, and Bohr's law of constant angular momenta.

According to the first law the amount of energy radiated from an atom is proportional to the frequency at which it is radiated, the constant h being the factor of proportionality. In other words the atom changes from one state into another when it radiates, and the difference between the energy it possessed before and after the radiation equals the frequency of vibration multiplied by h, thus:

$$h\nu = W_1 - W_2.$$

According to this conception the terms in the combination law represent the energy of the atom in its various states of equilibrium divided by h, plus, of course, an additive constant.

The complete expression of the law is

$$\tau h\nu = W_1 - W_2,$$

where τ denotes any whole number, but spectrum lines corresponding to values of τ greater than 1 have not been observed. They may be very faint, except, perhaps, in the infra red spectrum. The chance of τ's being greater than unity (in black body radiation) is very small for high frequencies of vibration.

Extraordinary success has attended the application of Bohr's theory to the case of a single electron revolving about an atomic nucleus. In this theory the angular momentum of the electron equals some whole number multiplied by a universal constant, $h/2\pi$, thus

$$mva = \tau(h/2\tau).$$

The value of the universal angular momentum may be regarded as chosen to fit the facts, *i. e.*, to give the correct value for the Rydberg fundamental frequency, or we may assume, with William Wilson, that a certain integral equation, occurring in the theory of quanta, expressed in generalized coordinates, namely,

$$\int pdq = \tau h,$$

applies to the revolving electron. Since the force acting on the electron is a central force, the angular momentum p is constant, and, if we take the integral over a complete period during which the angle q varies by 2π, we have

$$2\pi mva = \tau h.$$

As an example of the application of Bohr's theory let us consider the values of the Rydberg constant for hydrogen and for ionized helium. In each case a single electron revolves about an atomic nucleus. The theory assumes that the attraction between them is given by Coulomb's law, and from this together with the two laws mentioned above the various unknown quantities can be calculated, including the frequency of the emitted radiation. Since the helium nucleus is nearly four times as heavy as the hydrogen nucleus, the common center of gravity, about which the electron and the nucleus revolve, is slightly nearer the center of the helium nucleus, than is the case with hydrogen. Bohr predicted that on account of this fact certain lines in the hydrogen spectrum should have wave-lengths slightly longer than certain lines in the enhanced helium spectrum, and experiments prove this to be true. Further, the ratio of the mass of the electron to that of the hydrogen atom, and the ratio of the charge to the mass of the electron can be calculated from accurate measurements of the wave-lengths of these lines. The values of these ratios calculated from data obtained by Pashen are very nearly the same as the values deduced from other methods of experiment. In fact, granting the general truth of the theory, they are, perhaps, the most accurate estimates we have of these important ratios.

The Rydberg constant for the spectra of ordinary helium, in which we may suppose that there is one electron revolving in an inner ring about the nucleus, appears to be slightly less than that for the spectrum of ionized helium. Bohr's theory would seem to account for some such decrease in the value of the constant, for the influence of this electron on

electrons in outer rings is slightly greater than would be the case, if it were actually in the nucleus itself. The theory, applied to cases where more than one electron revolve about the nucleus, does not appear as yet to be thoroughly satisfactory.

Bohr's theory has been applied to the characteristic X-ray spectra with some success in particular cases. For instance, Sommerfeld's calculation of the frequency difference between the lines in the Kα group by means of elliptic orbits, etc., seems to represent the facts to a considerable degree of precision.

In general the theory does not indicate the distribution of the electrons among the various orbits, and this distribution must be determined by other considerations, or else it must be chosen to fit the X-ray data. The latter procedure has been followed by Debye, Kroo, Wiggard and Sommerfeld. The calculation of the frequency of the α_1 line in the K series by Sommerfeld seems to agree with the facts to a remarkable degree of accuracy. None of the formulas, however, appear to give the frequencies of all the lines in the X-ray spectra.

It might be interesting to calculate the frequencies of the critical absorption associated with the K series, using a distribution of electrons similar to that adopted by Lewis and Langmuir in their theory of a static atom. In this theory the inner shell contains two electrons, the second shell contains two layers of 8 electrons each, the third, two layers of 18 each, etc. Translating this distribution from the static atom over into the dynamic atom I shall assume that the inner orbit of one quantum ($\tau = 1$) contains 2 electrons; that outside this are two orbits of two quanta ($\tau = 2$), one just outside the other and each containing 8 electrons etc.

K ABSORPTION FREQUENCIES

The table contains the data. Two columns of calculated values are given, one corrected for the mutual influence of neighboring rings of electrons on each other and one uncorrected. The observed values represent our measurements of the critical absorption frequencies,[2] which are the highest X-ray frequencies known to be characteristic of the chemical elements. Except for aluminium the observed values differ from the calculated values by less than the correction for the influence of the rings on each other. Considering that none of the quantities used in the calculations have been taken from X-ray data, the agreement may be regarded as good, especially for the chemical elements of high atomic number.

The above distribution of electrons does not give the proper values for the frequencies of the emission lines of chemical elements of low atomic numbers, so that the problem can not be said to have been solved.

$$\frac{\nu}{\nu_0} = 2(N - \tfrac{1}{4} - \phi_1)(1 + \tfrac{1}{4}\beta_1^2 + \tfrac{1}{8}\beta_1^4 + \cdots) - (N - \phi_2)^2(1 + \tfrac{1}{4}\beta_2^2 + \tfrac{1}{8}\beta_2 + \cdots) + \Sigma \frac{n}{\tau^2}(N - n_1 - n_2 - \cdots - s_n - \phi)^2 - \Sigma \frac{n}{\tau^2}(N - n_1 - n_2 - \cdots - s_n - \phi + 1)^2.$$

$$\beta = \frac{2\pi e^2}{ch}(N - \phi).$$

$n_1 = 2,\ n_2 = 8,\ n_3 = 8,\ n_4 = 9,\ n_5 = 9,\ \cdots.$

$\tau_1 = 2,\ \tau_2 = 2,\ \tau_3 = 3,\ \tau_4 = 3,\ \cdots.$

ν_0 = Rydberg Fundamental Frequency

Chemical Element	Atomic Number	ν/ν_0 Calculated (Uncorrected)	ν/ν_0 Observed	ν/ν_0 Calculated (Corrected)
Aluminium	13	116.7	114.8	118.5
Phosphorus ...	15	157.0	158.4	163.9
Manganese	25	479.2	482.8	500.8
Bromine	35	968.9	993.6	1000.0
Rhodium	45	1696.0	1711.0	1717.0
Caesium	55	2584.0	2648.0	2643.0
Terbium	65	3752.0	3803.0	3812.0
Tungsten	74	5056.0	5109.0	5118.0

D. The Origin of Radiation, by A. W. HULL, of the Research Laboratory of the General Electric Co.

The rapidity with which our theories of atomic structure have advanced during the last ten years has left the impression that each new contribution was a new theory, and that one must choose between these appar-

[2] *Physical Review,* December, 1919.

ently conflicting theories. The purpose of this paper is to show that these contributions not only do not conflict, but that all of them are essential parts of a picture, which is nearer completion than most of us realize. The main contributions may be summarized as follows:

Ritz showed that by assuming the nucleus to be magnetic, so that the force determining the vibration of the electron depends on the velocity instead of the position of the electron, one obtains a frequency law involving only the first power of the frequency, in accordance with observations.

The essential part of Bohr's beautiful theory is the mechanism by which he accounts for Ritz's combination principle namely, that the frequency of radiation depends not on where the electron is, or where it came from, but upon both.

J. J. Thomson added the idea that Bohr's stable orbits, and the quantum relations connected with them, are due to a skeleton structure of the nucleus and not to any discontinuity of energy.

Sommerfeld extended Bohr's theory to atoms of higher atomic weight, and has drawn a beautiful picture. His main contribution is the idea that the orbit may be either a circle or an ellipse of definite eccentricity, which accounts with extreme precision for the separation of doublets both in X-ray spectra and the hydrogen spectrum.

Langmuir showed that all known chemical properties are satisfied by an atom with relatively stationary electrons, arranged in concentric shells about the nucleus.

By combining these contributions, namely, the magnetic nucleus of Ritz, Bohr's stable orbits, Thomson's skeleton nucleus, Sommerfeld's elliptical orbits, and Langmuir's stationary electrons, we arrive at a composite picture which represents our present knowledge remarkably well. The rotating point electron is replaced by a ring-shaped electron. The constant angular momentum of the rotating electron is replaced by constant magnetic moment of the ring. In the case of hydrogen and ionized helium the ring surrounds the nucleus, and the picture is identical with Bohr's. In the case of the other elements the rings lie on the surface of concentric shells, in positions corresponding to Langmuir's cells. The condition of constant angular momentum of each ring electron holds for all atoms, and Sommerfeld's picture of the circular and elliptical rings is applied to the shape of the ring electron.

The discussion following the symposium was of necessity brief. Emphasis was given to the clear advantage of preferring a theory of atomic structure that gives correct quantitative results.

G. W. Stewart,
Secretary Section B

SCIENTIFIC EVENTS

PUBLICATIONS AND MEMBERSHIP OF THE NATIONAL ACADEMY OF SCIENCES

At the recent meeting of the academy the home secretary presented the following report:

The President of the National Academy of Sciences.

Sir: I have the honor to present the following report on the publications and membership of the National Academy of Sciences for the year ending April 26, 1920.

Two parts of Volume 14 of the Memoirs of the National Academy of Sciences have been completed and distributed: the second memoir, "Complete Classification of Triad Systems," by H. S. White, F. N. Cole and L. D. Cummings, and the fourth memoir, "Minor Constituents of Meteorites," by G. P. Merrill.

The third memoir, "Tables of Minor Planets," by A. O. Leuschner, A. E. Glancy, and S. H. Levy, and the fifth and final memoir of Volume 14, "Tables of the Exponential Function," by C. E. Van Orstrand, are now in page proof and will be issued shortly, as will also Volume 15, "Psychological Examining in the United States Army," by Robert M. Yerkes.

Volume 16, first memoir, "Lower California and its Natural Resources," by E. W. Nelson, and the second memoir, "Studies upon the Life Cycles of Bacteria," by F. Löhnis, are now in galley proof. The third memoir, "A Recalculation of Atomic Weights," by F. W. Clarke, is now in the hands of the printer.

Volume VIII. of the Biographical Memoirs has been completed with the publication of the biog-

raphies of Benjamin Osgood Peirce, and Cleveland Abbe, and the bound volume distributed. The following biographies forming a part of Volume IX. have been completed and distributed: William Bullock Clark by John M. Clarke; Arnold Hague by Joseph P. Iddings; Eugene Waldemar Hilgard by Frederic Slate; James Dwight Dana, by L. V. Pirsson; James Mason Crafts, by Charles R. Cross; Lewis Boss, by Benjamin Boss, and Alpheus Spring Packard, by T. D. A. Cockerell. That of Charles Sedgwick Minot is now in page proof.

The Report of the National Academy of Sciences has been issued and the fourth Annual Report of the National Research Council will be issued in separate form in a few days. The Proceedings have reached the third number of the sixth volume.

Since the last meeting, two members have died. Louis V. Pirsson, elected 1913, died December 8, 1919, and Horatio C. Wood, elected in 1879, died in 1919. This leaves an active membership of 175 members, 1 honorary member and 31 foreign associates. Gustav Retzius, foreign associate, died on July 12, 1919.

C. G. ABBOT,
Home Secretary

MATHEMATICAL MEETINGS AT THE UNIVERSITY OF CHICAGO

THE twenty-seventh summer meeting and ninth colloquium of the American Mathematical Society will be held at the University of Chicago during the week beginning Monday, September 6, 1920. The sessions of the Mathematical Association of America will occupy Monday morning and afternoon. The council of the society will meet on Monday evening. The regular sessions of the society will occupy Tuesday morning and afternoon and Wednesday morning. The joint dinner of the society and the association will be held on Tuesday evening.

The University of Chicago will open two of its dormitories, one for men and one for women, during the week of the meeting, and meals will be provided on the university grounds. Advance information on these matters can be obtained from Professor H. E. Slaught.

The colloquium will open Wednesday afternoon and will extend through Saturday morning. It will consist of two courses of five lectures each, as follows: I. Professor G. D. Birkhoff, of Harvard University: "Dynamical systems." The last forty years have witnessed fundamental advances in the theory of dynamical systems, achieved by Hill, Poincaré, Levi-Civita, Sundman, and others. The lectures will expound the general principles underlying these advances, and will point out their application to the problem of three bodies as well as their significance for general scientific thought. The following topics will be treated: Physical, formal, and computational aspects of dynamical systems. Types of motions such as periodic and recurrent motions, and motions asymptotic to them. Interrelation of types of motion with particular reference to integrability and stability. The problem of three bodies and its extension. The significance of dynamical systems for general scientific thought.

II. Professor F. R. Moulton, of the University of Chicago: "Certain topics in functions of infinitely many variables." I. On the definition and some general properties of functions of infinitely many variables. II. On infinite systems of linear equations. III. Infinite systems of implicit functions. IV. Infinite system of differential equations. V. Applications to physical problems.

THE SOUTHWESTERN DIVISION OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

A MEETING of the council of the American Association for the Advancement of Science, held in Washington on April 26, approved the organization of the Southwestern Division of the Association, which was tenatively made in a meeting of delegates held at the University of Arizona, Tucson, Arizona, on Saturday, April 10.

At that meeting Dr. D. T. MacDougal was delegate from the American Association. Local delegates came from Prescott, Phoenix, and Tucson, Arizona Albuquerque, New Mexico and El Paso, Texas.

Dr. Edgar L. Hewett, of the School of American Research, director of the Archaeological Institute, director of the State Museum at Sante Fe, N. M., and the Archaeo-

logical Museum in San Diego, was elected president of the Southwestern Division; Elliott C. Prentiss, M.D., of El Paso, Texas, was elected vice-president and chairman of the executive committee; and Dr. A. E. Douglass, of the University of Arizona, was elected secretary and treasurer.

The executive committee in its membership besides the three officers just mentioned consists of Dr. John D. Clark, Albuquerque; A. L. Flagg, Phoenix; Fabian Garcia, Mesilla Park; Arthur Notman, Bisbee; Richard S. Trumbull, El Paso; Milton Updegraff, Prescott; and Charles T. Vorhies, Tucson.

A constitution was adopted. The area included in this Division will be Arizona, New Mexico and West Texas.

Dr. Edgar L. Hewett, the newly elected president of the Southwestern Division, gave a lecture entitled "Our Place in Civilization," at the University of Arizona, Tucson, on April 28 and at El Paso, Texas, on April 30. In connection with the formation of this division also Dr. A. E. Douglass, of the University of Arizona, gave a lecture entitled "The Big Tree and its Story," in Phoenix, Arizona on April 1.

THE RESIGNATION OF PRESIDENT DRINKER OF LEHIGH UNIVERSITY

Dr. Henry S. Drinker has addressed to his fellow-alumni of Lehigh University, the following letter:

I have felt for some time and have so stated, informally, to the members of our board of trustees, that as I reach the age of seventy this year, it would be the part of wisdom for me to retire from the presidency of the university. I have therefore tendered my resignation to take effect at the close of the commencement exercises on June 15th next. So far as I know, I am in perfect health and in good strength, but I wish to retire while my friends still feel they desire my services to continue. I am not willing to hold on for some time, as I might do, and then feel that increasing years and failing powers compel my retirement.

From the time of my graduation in June, 1871, I have been devoted to the service of the university's interests, and have served as secretary of the alumni, president of the alumni, alumnus trustee, trustee and president, and now in proposing to drop out of active presidential duties, I have no thought of lessening my interests in the alma mater, nor is my retirement from the presidency prompted by any thought except that I have accomplished the things for which I came here, and I now wish to see the leadership of the university pass into the hands of a younger man, one qualified by educational training and actual large experience in educational work, and possessing marked executive ability. I am satisfied that the university has reached a stage in its existence requiring for its leadership and guidance, a man possessing these characteristics.

It has been my privilege to bring to the service of the university energy, devotion and business experience. It was thought at the time of my election, when the university was in financial strain, and in need of greater facilities in plant and equipment and a larger teaching force, that the energies of its friends should be directed to these ends, and I was asked to undertake the task. To-day, with our plant in greatly improved shape, with our faculty increased from 15 in 1905, to 33 in 1920, the entire teaching force raised from 57 to 89, with our financial situation greatly improved and comparing favorably with that of our competitors, our present need is, as above stated, for a man experienced and trained in educational methods, and with good executive ability; I feel content in the knowledge that our board of trustees will well consider the situation, and fittingly serve our university's needs.

SCIENTIFIC NOTES AND NEWS

At the recent meeting of the National Academy of Sciences the following foreign associates were elected: Frank Dawson Adams, McGill University; Marie Ennemond Camille Jordan, Collège of France; François Antoine Alfred Lacroix, Musée d'Histoire Naturelle, Paris; Heike Kamerlingh Onnes, University of Leyden; Sir David Prain, Royal Botanic Gardens, Kew, Surrey; Santiago Ramon y Cajal, University of Madrid.

The National Academy of Sciences has recommended to Columbia University that the Barnard medal be conferred on Albert Einstein "for highly original and fruitful development of the fundamental concepts of physics through the application of mathematics." The Agassiz medal has been awarded to Admiral C.

D. Sigsbee, U. S. N., retired, "for his important contributions to oceanography, both by actual research, by publication of his results and invention of new methods."

IN recognition of successful scientific research in the prevention of disease and the conservation of health, Dr. Theobald Smith, head of the Laboratory of Comparative Pathology of the Rockefeller Institute and formerly of Harvard University, has been voted the M. Douglas Flattery Medal and $500 in gold by the Harvard Corporation. The medal is awarded to the man of science whose efforts have proved of the greatest value to mankind in fighting disease.

A PORTRAIT of Dr. William H. Welch, of the Johns Hopkins University, president of the University Club of Baltimore, was presented to the club recently at its monthly meeting.

DR. W. W. KEEN has been elected an honorary fellow of the Royal Society of Medicine, London, and of the American Surgical Association.

DR. RAYMOND F. BACON, director of the Mellon Institute of Industrial Research of the University of Pittsburgh, who during 1918, was a colonel serving as chief of the Technical Division of the Chemical Warfare Service, A. E. F., has been awarded a citation by General Pershing for exceptionally meritorious and conspicuous services in France.

PROFESSOR SADAO YOSHIDA, of Osaka Medical College (Japan), has been awarded the Katsurada prize and medal of honor established by the Japanese government to be given periodically to some distinguished worker on tropical diseases. Professor Yoshida is spending his sabbatical year in research at the Parasitological Laboratory of the University of Illinois.

MR. VILHJALMUR STEFANSSON has been awarded the La Roquette Medal of the Geographical Society of Paris. He had previously been awarded the following medals: In December, 1918, the Daly Medal of the American Geographical Society, New York; in December, 1918, the medal of the Explorers Club of New York; in January, 1919, the Hubbard Medal of the National Geographical Society, Washington; in January, 1919, the Kane Medal of the Geographical Society of Philadelphia; in March, 1919, the Cullum Medal of the Chicago Geographical Society. All these medals are known as gold medals but at Mr. Stefansson's request they have been struck in bronze and the difference in cost has been given to Madame Beuchat, the mother of the distinguished scientific man, Henri Beuchat, who died on the expedition.

PROFESSOR KONRAD ROENTGEN retired from his chair of experimental physics at the University of Munich and resigned the charge of the Physikalisches Institut at the end of the winter semester.

THE board of trustees of the University of Pennsylvania has accepted the resignation of Provost Edgar Smith to take effect June 30. Dr. Smith presented his resignation last February. In accepting it now the board made him emeritus professor of chemistry and placed at his disposal the Harrison laboratory, where Dr. Smith expects to devote the greater part of his time to research work.

DR. EDWARD T. REICHERT, professor of physiology in the Medical School of the University of Pennsylvania, has retired from active service.

AT the annual meeting of the Kentucky Academy of Science held in Lexington on May 8, the following officers were elected: *President,* Professor W. H. Coolidge, Centre College, Danville, Ky.; *Vice-President,* Professor George D. Smith, Eastern Kentucky State Normal School, Richmond, Ky.; *Secretary,* Dr. A. M. Peter, Experiment Station, Lexington, Ky.; *Treasurer,* Mr. J. S. McHargue, Experiment Station, Lexington, Ky.

DR. A. HRDLIČKA, of the U. S. National Museum, has returned from a trip to the Far East He visited Japan, Korea, Manchuria, northern China and Hawaii.

MR. IRVING PERRINE, vice-president of the American Association of Petroleum Geologists, is moving his office from Hutchinson, Kansas, to 1415 West 31st Street, Oklahoma City,

Okla., and will there continue his work as a consulting petroleum geologist.

Dr. Ira Remsen, of the Johns Hopkins University, will deliver the commencement address at West Virginia University on June 15.

Dean W. M. Wheeler, of Bussey Institution, Harvard University, delivered an address under the auspices of the Society of Sigma Xi of Syracuse University, on May 6. The address, which was on "Worm-lions, ant-lions and some eighteenth-century entomologists," covered the observations made by Réaumur and other early naturalists upon the habits of the worm-lion and ant-lion; and included the studies of the lecturer upon the structure and behavior of the worm-lions of California.

Dr. G. M. Stratton, professor of psychology at the University of California, has given the Nathaniel W. Taylor lectures at the Yale School of Religion.

Dr. George F. Kay, head of the department of geology, State University of Iowa, and state geologist of Iowa, lectured on April 21 before the chapter of Sigma Xi of the University of Minnesota, on "The History of Glaciation in the Mississippi Valley."

Dr. C. E. Kenneth Mees, director of the research laboratories of Eastman Kodak Co., landed in England April 27. While there he will deliver the following lectures before various scientific bodies: "Some Photographic Phenomena in Relation to Astronomy," "Some Results of Recent Investigations on the Theory of Development," "Photography of the Air," "Reaction of the Eye to Light," "A Photographic Research Laboratory," "The Production and Supply of Synthetic Organic Chemicals in the United States," "Rochester and the Kodak Works," "Scientific Research and Industrial Production," "The Theory of Tone Reproduction with a Graphic Method for the Solution of Problems."

Dr. Harry N. Holmes, head of the chemistry department of Oberlin College and chairman of the National Research Council's Committee on Colloids is on a five weeks lecture tour to the Pacific coast. The series of from one to four lectures on "Colloid Chemistry" will be given at Northwestern University, Los Angeles, San Francisco and Seattle Sections of the American Chemical Society, University of Washington, State College of Washington, Montana School of Mines, Montana State College, State College of North Dakota, University of Wisconsin, Iowa State College (Ames), Leland Stanford University and the University of California.

Dr. Joseph Simms, a well-known lecturer and traveler, who died of cerebral hemorrhage in New York City on April 11, in his eighty-seventh year, bequeathed his body to Dr. Edward A. Spitzka for scientific study. The brain of Dr. Simms, removed eighteen hours after death, weighed 1,520 grams (53.58 onces avoirdupois) and has been preserved by Dr. Spitzka for the detailed study of its morphologic features in comparison with the brains of other notable men.

It is stated in *Nature* that botanists in Great Britain have been considering the practicability of holding an Imperial Botanical Congress in London at which botanists from the overseas Dominions might meet their colleagues at home for the discussion of matters of common interest. Many subjects are ripe for discussion, such as the methods of training botanists for service abroad, the relation between the pure science and its applications and between the botanist and the commercial men interested in industries in which botanical knowledge should play an important part, more helpful cooperation between the home and the overseas botanist, botanical surveys of overseas Dominions, and others. After careful consideration it has been decided that it would be inadvisable to hold such a congress during the present year.

UNIVERSITY AND EDUCATIONAL NEWS

The medical departments of Columbia, Harvard and the Johns Hopkins Universities receive $5,541,401 each, in the distribution of the estate of Captain Joseph R. De Lamar. The will, disposing of a sum of thirty-two million dollars, provides these funds for the study and

teaching of the origin and cause of disease and its prevention and for the study and teaching of dietetics.

HOWARD UNIVERSITY SCHOOL OF MEDICINE, Washington, has been promised $250,000 by the General Education Board, provided the medical school succeeds in raising the rest of a total sum of $500,000.

THE trustees of the University of Southern California, on April 13, decided to suspend temporarily the medical department because of inadequate endowment with which to maintain it.

DR. CORNELIUS BETTEN, secretary of the State College of Agriculture at Cornell University, has been appointed vice-dean of the college.

CURT ROSENOW (Ph.D., Chicago, 1917), of the Juvenile Psychopathic Institute, Chicago, has accepted an assistant professorship in psychology at the University of Kansas.

DR. A. RICHARDS, professor of zoology at Wabash College, has been appointed to a professorship of zoology in the University of Oklahoma, where he will be head of the department.

DR. FRED HOFFMANN RHODES has been appointed professor of industrial chemistry and will begin his work in the autumn at Cornell University.

GENERAL SIR ARTHUR CURRIE has accepted the position of principal of McGill University in succession to Sir Auckland Geddes, who resigned to become British Ambassador at Washington.

DISCUSSION AND CORRESPONDENCE

FORMULÆ GIVING THE DAY OF THE WEEK OF ANY DATE

To officials who are required to fix the dates of events beyond the end of the current year and to historians who may desire to know the day of the week of events in past years, for which calendars are not ordinarily available, the formulæ given below may be of considerable interest.

When the days of the week are numbered thus:

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
1	2	3	4	5	6	0

the day of the week of any date in the Gregorian (New Style) calendar is the remainder, R, in the division

$$(Y + 3C + F + L + M + D)/7 = Q + R/7,$$

in which the symbols used have the following meanings:

Q is the integral part and R the remainder obtained in the division indicated in the first member of the equation.

Y is the year in which the date occurs.

C is the number formed by striking out the last two digits of the year. Thus, for dates in the year 1920, $C = 19$.

F is the number of preceding leap days occuring in centennial years. These occur in the years 400, 800, 1200, 1600, etc. Thus, for dates between

Jan.	1,	1,	and	Feb. 29,	400,	inclusive,	$F = 0$
Mar.	1,	400,	"	" "	800,	"	$F = 1$
Mar.	1,	800,	"	" "	1,200,	"	$F = 2$
Mar.	1,	1,200,	"	" "	1,600,	"	$F = 3$
Mar.	1,	1,600,	"	" "	2,000,	"	$F = 4$

L is the number of leap days between the date and the last centennial year (not inclusive). It it the quotient obtained by dividing by four the number formed by the last two digits of the year in which the last preceding leap day occurred.

M is a number which varies from month to month as follows:

Jan.	Feb.	Mar.	Apr.	May	June
0	3	3	6	1	4
July	Aug.	Sep.	Oct.	Nov.	Dec.
6	2	5	0	3	5

D is the day of the month.

Examples:	Oct. 21, 1492	Feb. 22, 1732	Oct. 22, 1863
$Y =$	1492	1732	1863
$3C =$	42	51	54
$F =$	3	4	4
$L =$	23	7	15
$M =$	0	3	0
$D =$	21	22	22
	$7\overline{)1581}$	$7\overline{)1819}$	$7\overline{)1958}$
	$225\frac{6}{7}$	$259\frac{6}{7}$	$279\frac{5}{7}$
$R =$	6 = Fri.	6 = Fri.	5 = Thu.

For dates in the Julian (Old Style) calendar the formula is

$$(Y + 4C + L + M + D + 5)/7 = Q + R/7,$$

in which the various symbols have the same meanings as above.

Examples:	Oct. 12, 1492	Feb. 11, 1732	July 4, 1920
$Y=$	1492	1732	1920
$4C=$	56	68	76
$L=$	23	7	5
$M=$	0	3	6
$D=$	12	11	4
	5	5	5
	7)1588	7)1826	7)2016
	$226\frac{6}{7}$	$260\frac{6}{7}$	$288\frac{0}{7}$
$R=$	6=Fri.	6=Fri.	0=Sat.

W. J. Spillman

ORIGIN OF THE SUPPOSED HUMAN FOOTPRINTS OF CARSON CITY, NEVADA

During the summer of 1919 the writer found occasion to visit Carson City, Nevada, and, through courtesy of members of the prison staff at the Nevada State Penitentiary, was enabled to examine a number of specimens of fossil mammals collected in the prison yard during past quarrying operations for building stone. In the material preserved in the collections were fragments of a skull and a cervical vertebra belonging to a ground sloth. Warden R. B. Henrichs, of the Nevada prison, was kind enough to loan the remains recovered during the excavations to the department of paleontology, University of California, and further study indicates that the ground sloth specimens pertain to an individual of the genus *Mylodon*.

Many years ago the discovery of footprints, bearing a superficial resemblance to imprints made by a human foot, in a shale stratum exposed in the yard of the penitentiary at Carson City, gave rise to the view that the existence of primeval man in Nevada was definitely established—a view that has taken a particularly tenacious hold. The possibility that the footprints were in reality those of a ground sloth, presumably of a form related to the South American *Mylodon*, was, however, advocated by Joseph Le Conte,[1] O. C. Marsh[2] and others. In 1917, the writer[3] contrasted the outline of the so-called human footprints with that of a complete hind foot of *Mylodon harlani* reconstructed from remains of this species secured in the asphalt deposits at Rancho La Brea. The great resemblance which the articulated foot bore to the impressions, both in outline and in size, seemed certain proof that the latter were left by *Mylodon*.

The actual occurrence of osseous remains of *Mylodon* in the Pleistocene deposits at Carson City, Nevada, removes still farther the possibility that the Carson footprints are to be attributed to a member of the Hominidæ and materially substantiates the suggestions of Le Conte and Marsh. Further, the presence of material referable to a mylodont sloth gives a high degree of probability to the contention that the footprints were made by *Mylodon* rather than by some other quadruped.

Chester Stock
University of California

SCIENTIFIC PHOTOGRAPHY

To the Editor of Science: The Royal Photographic Society of Great Britain is holding its sixty-fifth annual exhibition in September and October of this year. This is the most representative exhibition of photographic work in the world, and the section sent by American scientific men heretofore has sufficiently demonstrated the place held by this country in applied photography. It is very desirable that American scientific photography should be equally well represented in 1920, and, in order to enable this to be done with as little difficulty as possible, I have arranged to collect and forward American work intended for the scientific section.

This work should consist of prints showing the use of photography for scientific purposes and its application to spectroscopy, astronomy,

[1] Le Conte, J., *Proc. Calif. Acad. Sci.*, 10 pp., August 27, 1882.

[2] Marsh, O. C., *Amer. Jour. Sci.*, Ser. 3, Vol. 26, pp. 139–140, 1883.

[3] Stock, C., Univ. Calif. Publ. Bull. Dept. Geol., Vol. 10, pp. 284–285, 1917.

radiography, biology, etc. Photographs should reach me not later than Thursday, July 1. They should be mounted but not framed.

I should be glad if any worker who is able to send photographs will communicate with me as soon as possible so that I might arrange for the receiving and entry of the exhibit.

A. J. NEWTON

EASTMAN KODAK COMPANY,
ROCHESTER, N. Y.,

QUOTATIONS

COMPETITION IN RESEARCH

THE resignation of Professor Ernest Fox Nichols from the department of physics at Yale University in order to continue his research work upon a larger scale in the Nela Research Laboratories of the National Lamp Works at Cleveland, offers a new impression of the possible utilization of professional talent. Professor Nichols resigned the presidency of Dartmouth College to come to Yale where there was a greater promise of his continuing his scientific work, and now leaves Yale to enter the employ of a private corporation whose opportunities for scientific work on a much enlarged scale are even greater.

The loss to Yale of the fine influence of Dr. Nichols' personality is obvious. That is something to be deeply regretted but, taking him as a type of trained scientists, whether the withdrawal of such men from the universities of the country and their employment by large corporations whose interest in scientific research is more direct is to the common disadvantage may seriously be questioned. The limitations which are necessarily set upon work of this character even in the best equipped of university laboratories disappear in corporations where no limitations are set when the importance of the end sought is realized. In the case of Dr. Nichols the work which he wishes to accomplish has such great importance in its actual accomplishment that his transfer must be considered as of greater general advantage because it may be accomplished the earlier under private rather than under university encouragement. The theoretical disadvantage which results to the university is in all likelihood offset by the practical advantage to be commonly gained.

Speculation is here invited as to what the effect will be upon the teaching force of a university if the labor of research work of a scientific character is to be taken over by private corporations. We might imagine affirmative and the negative coming to blows over this thesis at least until the lessons of experience have been written into the record. —*The New Haven Journal-Courier.*

A NEW STATISTICAL JOURNAL

THERE has recently been founded a new international statistical journal called *Metron*. It is published at Padua, Italy, at a subscription price of 40 lire per year. The printer, where subscriptions should be sent, is the *Tipografia Industrie grafiche Italiane*, Via Viscovado, Padova, Italy. The journal will appear quarterly, each number comprising 150 to 200 pages.

The founder and chief editor of *Metron* is Professor Corrado Gini, of the University of Padua. The fact that so brilliant and sound a worker as Professor Gini is to be in charge at once guarantees the scientific standing of the journal in the statistical field. An international editorial board has been formed, which now includes the following persons:

Professor A. Andreadès, de science des finances a l'Université de Athenes (Greece),

Professor A. E. Bunge, directeur de la Statistique de la Republique Argentine, Buenos Ayres (Argentine),

Dr. F. P. Cantelli, actuaire au Ministere du Tresor, Rome (Italy),

Dr. L. V. Furlan, libre docent de statistique a l'Université de Bâle (Switzerland),

Dr. M. Greenwood, reader of medical statistics in the University of London; statistician of the Lister Institute, London (England),

Dr. A. Julin, directeur de la Statistique economique de la Belgique Ministère de l'Industrie et du Travail, Bruxelles (Belgium),

Dr. G. H. Knibbs, directeur de la Statistique de la confederation australienne, Melbourne (Australia),

Ing. L. March, directeur de la Statistique générale de la France, Paris (France),

Dr. Raymond Pearl, professor of biometry and vital statistics, School of Hygiene and Public Health, Johns Hopkins University, Baltimore, Maryland (United States).

The general editorial program may be set forth as follows:

One of the great difficulties in connection with modern statistics is that of becoming acquainted with the relevant literature; this is in fact derived from the work of very different schools and published in a variety of journals and transactions. It is necessary to consult mathematical, astronomical, technical, physical, chemical, actuarial, economic and financial, psychological, historical, legal, physiological and pathological, hygienic and medical, biological, genetic and eugenic and even purely zoological, botanical and agricultural publications.

It is true that generally such papers are merely applications of interest to specialists in the particular branch of knowledge. But this is not always the case and sometimes methods of general interest to all statisticians are to be found, or, again, we find in particular connections methodological problems enunciated and solved, the scope of hypotheses contained in certain analyses brought to light, the approximation of theoretical conclusions verified and advances made by different routes; progress of interest in all branches of statistics. Still more frequently the results of particular statistical investigations, even when they do not interest all statisticians, are of importance to those engaged in similar inquiries: thus results obtained in the field of anthropology, zoology, genetics or eugenics, hygiene, medicine, pathology, life insurance, political economy or history may be of great interest to the student of demography.

Whoever, desiring to enlarge the boundaries of statistical science as far as possible, is forced to consult the heterogeneous literature containing statistical papers must be aware of the inconvenience resulting from lack of coordination.

Valuable statistical data, carefully collected, scrupulously criticized, remain of no scientific value owing to their presentation and analysis by those unskilled in modern methods. Typographical difficulties offer obstacles to the publication of the original data in their integrity so that competent statisticians are unable to harvest the grain which the original author had not the skill to reap. Sometimes we meet with tedious, inconclusive, or even fallacious arguments where quite an elementary knowledge of statistical methods would have led to a simple and exact conclusion. Sometimes indeed we merely encounter—and this is the smallest evil—the rediscovery of an established truth or the reinvention of a familiar method, but how often do we not feel in reading the work of a writer, sagacious and profound in his own subject, that he would have greatly profited by a knowledge of other statistics published in journals quite disconnected from his specialty!

Within the limits appropriate to a review, *Metron* will endeavor to take the first step towards remedying these defects. It is addressed to those who, cultivating different soils with various implements, nevertheless are busied with statistics; that the results of their labors may become of general utility to science. It is hoped that *Metron* may be a bond of union between statistical workers in different branches, perhaps at length an organ of scientific coordination.

With this object, *Metron* will be catholic; its pages will be open to those who employ no methods beyond the scope of ordinary cultivated men as well as to those who delight in the most refined and subtle developments of mathematical science. There is indeed scope for both schools. Some problems can be solved by the older methods now part of the intellectual stock of all educated persons, others must be investigated with the help of more recondite procedures. Between these extremes are insensible gradations and both orders of inquiry interest science in general and statistical science in particular. It is hoped that both will find in *Metron* an appropriate treatment.

It can not of course be denied that, the simpler the methods employed, the easier is

the process of mutual enlightenment which *Metron* is intended to facilitate, since the number of readers capable of profiting by the exposition will be larger. The editors hope therefore that questions will be dealt with as their nature permits. But this is merely the expression of a desire not a condition of publication. The editors do not desire to put any compulsion upon contributors or to gainsay those who will forego a numerous audience for the satisfaction of expressing their ideas in the most concise and accurate style.

The sole necessary condition of approval for publication is that papers shall make a contribution to the theory or practise of statistics of original value and likely to interest a greater or smaller number of students of statistics. Contributions will be inserted as articles or notes in accordance with the importance of the subject matter. Frequently statistical researches lead to fragmentary results, insufficient to form the subject of a paper or even a note, but still offering something of scientific interest or perhaps filling a lacuna in other investigations. Such results will be published under a special heading.

In addition to a bibliography of publications received, each number of the review will contain one or more analyses of statistical works or of results perhaps taken from works not exclusively statistical in character. Each such analysis will deal with a particular branch of statistics, *e. g.*, demographic, sanitary, anthropometric or economic statistics. There will also be an analysis of sources and of mathematical work bearing upon statistics (calculus of probabilities, interpolation, etc.).

Metron is an international review. As it is published in Italy and consequently a majority of the editorial staff are Italians, no doubt the Italian language will at first preponderate in its pages. But the other great international languages, French, English and German, are admitted to its pages on terms of complete equality. It rests with contributors from other countries to increase their share in its pages and to cause to disappear any such difference. It is the wish of the editors that the participation of non-Italian writers shall become larger and larger.

It is believed that many American workers, in the fields of biology, agriculture, and genetics particularly, as well as statisticians in the narrower sense, will be interested in this new journal and wish to have it in their libraries, as well as to use it as a medium of publication.

RAYMOND PEARL

SPECIAL ARTICLES

FOOT-ROT OF WHEAT

EARLY last spring attention was called to the occurrence of a foot-rot of wheat in Madison Co., Illinois. Since that time I have made a study of the disease assisted at first by Mrs. E. Young True, employed by the Illinois Natural History Survey, and later by Mr. George H. Dungan, of the Illinois Agricultural Experiment Station.

From the first it appeared probable that a certain fungus was the cause of the disease and as early as last June our notes show that this fungus was universally present and that inoculations with pure cultures gave positive results. The evidence is now so clear and conclusive that I venture to present the following facts as fully established.

1. This fungus was isolated by transfer to agar plates from diseased lesions in practically every case where the attempt was made, even when superficial leafy coverings were stripped away and the remaining surfaces disinfected with mercuric chlorid. In all several hundred such isolations were made. Reports from pathologists in other states indicate similar findings there.

2. No other species of fungus or parasite of any kind, was constantly present, or present in any large percentage of cases.

3. The diseased lesions were always penetrated and largely occupied by a fungous mycelium that agrees in general character with the fungus in question.

4. The diseased wheat stems when placed in conditions of suitable humidity become covered with spores of the fungus.

5. This fungus when inoculated in pure culture, either as spores, mycelium or infected wheat tissue, on the unwounded lower internodes of wheat seedlings in moist chambers produced a condition of disease indistinguishable from foot-rot as it occurred in the field.

6. Plants thus inoculated when placed in a moist chamber soon bore numerous spores of the fungus.

7. Wheat planted in soil in pots or benches with an inoculum consisting of this fungus, either as spores or as a pure culture on wheat, developed typical foot-rot.

8. Wheat when planted in infested soil in the greenhouse developed typical foot-rot and when placed in a moist chamber bore the same fungus found so constantly in association with the disease in the field.

9. The fungus in question is a typical *Helminthosporium* as the genus is now understood. It grows luxuriantly on wheat agar, corn meal agar and numerous other media and on autoclaved leaves or stems of various cereals. The spores, observed as grown on autoclaved wheat leaves or stems in humid air, are from 24 to 122 μ long, the majority of them falling within the limits 80–90 μ with septa or pseudo-septa varying from 0 to 13, usually about 5–10. The spores are typically thickest in the region about midway between the base and the middle point of the spore, approaching a narrow or broadly elliptical shape, tapering somewhat toward each end. They possess an outer dark wall that is thin and extremely fragile and an inner, colorless, thick wall that is frequently soft, gelatinous. Both of these characters of spore wall seem to be common in several other species of *Helminthosporium*. The spores usually, perhaps always, germinate either from one or both ends, not laterally, and are functionally one-celled.

Further discussion of the morphological and histological features and the relation of this *Helminthosporium* to other species common on cereals will be presented later.

All of the above refers solely to foot-rot as observed and studied in material originating in Madison Co., Illinois, or cultures derived from such material.

It is to be noted that this cereal disease, while of the general type of foot-rot known heretofore in Europe, Australia and elsewhere, is caused by an organism not heretofore designated as a cause of foot-rot in any of the publications on foot-rot in such countries.

The foot-rot found in Illinois, therefore, should be recognized as a disease quite distinct from all others of similar type that have been described previously. It is clear from experimental evidence that it is soil-borne and it is probable that it is also seed-borne. How serious the disease may prove to be, how dependent upon environmental conditions of climate and soil, can be told only after one or more years of additional observation.

F. L. Stevens
University of Illinois,

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SECTION E—GEOLOGY AND GEOGRAPHY

A Biochemical theory of the origin of Indianaite: W. N. Logan.

Our decreasing natural gas supply: J. A. Bownocker. A study was made of the natural gas supply from the records of four large companies in West Virginia, Pennsylvania and Ohio. It was shown that the open flow of new wells in West Virginia has decreased 79 per cent. in 10 years; in northwest Pennsylvania 70 per cent. in 7 years, and in southwest Pennsylvania 12 per cent. in 10 years. Changes in rock pressure of new wells are similar. Thus in northwest Pennsylvania there has been a decrease of 37 per cent. in 7 years, and in southwest Pennsylvania a decrease of 34 per cent. in 10 years. In the northern half of West Virginia there has been a decrease of 38 per cent. in the same period. Naturally there has been a proportional decrease in the rock pressure and open flow of all wells. In Ohio the drilling of new territory has kept the averages at a higher figure, but in spite of this the production of gas in the state is decreasing. Ohio gets 60 per cent. of her supply from West Virginia; Pennsylvania about 33 per cent.; Kentucky about 75 per cent., while Maryland and Indiana each draw on the state in a limited way. Manifestly the future supply depends largely on West Virginia. For the two years closing June 30,

1919, the production of natural gas in that state decreased 20 per cent.

Some characteristics of the Balcones fault zone in Bexar county, Texas: E. H. SELLARDS. The Balcones fault zone lies at the inner margin of the Coastal Plains of Texas, and the scarp resulting from the faults is a conspicuous topographic feature which in several counties separates the coastal plains from the high plains of the interior. The fault scarp is most pronounced in Uvalde, Medina, Bexar, Comal, Hayes and Travis counties. The formations observed to have been affected by these faults are those of the Lower and Upper Cretaceous and Eocene, while the Pleistocene formations have not been observed to be affected by faulting. Hence the age of the faults may be between Eocene and the Pleistocene. The number of faults within the fault zone as developed in Bexar county can scarcely be estimated. A few are seen at the surface; a number of others are located by well records, but with little doubt there are many more faults than have been located by either of these methods. They are normal faults with the downthrow to the south in most cases. The faulting is accompanied in some places by gentle folding, and the small oil fields of this county are found apparently upon structurally high areas produced by a combination of faulting and more or less folding. The width of the zone of faulting approximates 25 miles, and yet it remains to be determined how much farther to the south or southeast faulting in this zone may be detected.

The Ozarkian of Missouri: E. B. BRANSON.

The nature of Beatricea undulata: W. H. SHIDELER.

The possibility of a relationship between crystal types and the mode of occurrence of minerals: W. A. TARR. Along with other lines of research on the origin of crystals, the question arises as to whether the mode of occurrence shows an influence upon the type in which a given mineral crystallizes. If physical conditions influence the molecular arrangement this should be the case. A study of 128 common minerals, classified into eight zones shows that there is only a very general influence. The influence of composition appears to be more marked. The higher classes of symmetry are the most abundant in certain zones, yet physical factors do not appear to control the class of symmetry of a mineral. In large groups the physical conditions appear to be a factor but it is questioned whether the chemical factors are not of vastly more importance in these same zones.

An analysis of the process of thrust-faulting: T. T. QUIRKE. It is probable that there is so sharp a zone of division between the surficial plastico-frangible crust and the interior plastico-rigid mass that the part subject to rupture may be considered a separate member even though flow deformation may extend beneath it. Earth stresses due to the adjustment of a plastico-frangible crust to a shrinking interior affect members as wide as the continents and oceans are broad. These members fail near the ends under a stress which is rotational and unequally transmitted throughout the length of each member. The members fail after flexure somewhat in the manner of long columns. This type of rupture combined with a rotational stress makes a strong tendency to rupture at angles low at depth and high near the surface. Immediately after rupture a geologic process of abrasion comes into play. Abrasion is greatest where friction is most intense, at the steep parts of the fault plane. This movement of millions of tons of rock passing several miles along the fault plane will abrade the steep part of the plane to a lower angle and project to the surface the original low angle break. From which it follows that there may be a relation between the steepness of angle and the amount of displacement after rupture.

The mechanical interpretation of joints: WALTER H. BUCHER. On Mine Fork, Magoffin county, Ky., at the crest of an anticline in the upper third of a thick sandstone formation exposed in nearly vertical cliffs, two systems of joints are seen intersecting at an angle of approximately 120°, which is bisected by the horizontal direction. In this case, undoubtedly the joint planes, representing planes of shearing, were formed by simple tension and were arranged in such a way as to have the direction of maximum tension bisect the obtuse angle. In 1896 the French engineer Hartmann published the results of extended experimentation on the planes of shearing in metals, in which he found that the angle formed by the yield planes differs the more from 90° the harder and the more brittle the material is, and that the direction of maximum tension bisects the obtuse angle while that of minimum tension (generally negative, *i. e.*, compression) bisects the acute angle. O. Mohr, in 1900, gave a mathematical theory to account for this behavior. The author demonstrated the usefulness of this relation in interpreting the stress conditions underlying the fracturing of materials in well-known tension, compression and torsion tests. He then proceeded to apply this method to a number of joint systems taken partly from liter-

ature and partly from his own field observations, illustrating the three possible types of joint systems (1) max. tension = horizontal, min. tension = vertical (weight of overlying beds); (2) max. tension = horizontal (anticlinal bending), min. tension = horizontal and at right angles together (synclinal bending); and (3) max. tension = vertical (upward relief), min. tension = horizontal.

Notes on concretions: W. A. Tarr. Concretions found in a black shale of the Pennsylvanian in Boone county, Missouri, are believed to be syngenetic in origin. Reasons for so believing are the composition of the concretions (mainly clay and silica), the arching of the beds over them, absence of stratification lines passing through the concretions, lack of evidence of lateral crumpling, slickensides due to the consolidation of the beds around the concretion, and the volume of the concretions.

The Devonian of Ralls county, Missouri: Gilbert P. Moore.

Notes on the coal industries of northeastern France, Belgium, the Saar District and Westphalia: H. F. Crookes.

Data gathered by the writer for the War Damages Board of the American Commission to Negotiate Peace, in Paris, on the coal industry of western Europe, shows, among other things, that, of the reserves of coal, Germany now controls 28 per cent., England 49 per cent., France 7 per cent. and Belgium 4 per cent.

The acquisition by France of the Saar district does not solve that country's future requirements of coking coal for her Lorraine iron ore, because of the fact that it is impracticable to smelt the ore with Saar coke unless it is mixed with about 20 per cent. of Westphalian or equally good coke. Taken alone, Saar coke has been found to have about 67 per cent. the efficiency of Westphalian coke.

With the opening up of the Campine Basin in Belgium, France will be able to reduce her coke imports from Westphalia, but, even so, she must rely on the latter district for her principal supply of blast furnace coke.

Aside from a gain in actual coal reserves of over 16 billion tons, it is estimated that the net monetary gain by the acquisition of the German interests in coal lands, mines, equipment and coke plants in the Saar district is 411 million francs.

The dependence of the French and Belgian metallurgical industries on Westphalian coke is offset by the former's control of iron ore, for France now controls about 85 per cent. of the iron ore reserves of Europe. It has been advocated that a portion of the German indemnity be paid annually in terms of Westphalian coke. This would permit of the entire domestic coal production of both France and Belgium being diverted to industries other than metallurgic, but at best would be only a temporary arrangement. The exchange of iron ore for Westphalian coke, arbitrated by a committee from each country, might be a better solution, and is one that has been recommended.

The influence of the differential compression of sediments on the attitude of bedded rocks: Maurice G. Mehl. The diminution of the height of a column of sediment upon consolidation is brought about chiefly by the loss of water through the weight of the column. The rate of compressibility for shales is greater than for sands because of the differences in the shape of the particles. In the plate-like particles of shale there is a larger surface and hence a greater separating water film per unit volume of shale. The compressibility of sand is very slight while for shale it may be as high as 20 per cent. It follows that any difference in the total thickness of types of sediments with different rates of compressibility in adjacent columns will impart secondary dips to all beds above the irregularities. Unequal thicknesses of totals may arise through the lateral gradation of one type into another or through the actual thinning of a bed of a given type. Likewise any irregularity on an unyielding depositional surface will tend to produce different totals in the overlying columns of sediments. While the small isolated dome-like anticlines typical of the Mid-Continent oil field may have acted as localizing influences for the expression of later thrusts acting through great distances it is thought that these small structural features are chiefly the result of the differential compression of sediments.

Compression of sediments as a factor in the formation of coal basins: E. B. Branson.

On the Pennsylvanian stratigraphy in the mid-continent region: R. C. Moore.

Episodes in Rocky Mountain orogeny: C. L. Dake. West of Cody, along Greybull and Shoshone Rivers, are a series of yellow sandstones and red and gray shales with conglomerate layers. The conglomerates, which include granite pebbles, involve erosion down to the pre-Cambrian, and the beds rest with slight angular unconformity on the Cody (Niobrara and Pierre) shale. These conglomerates are themselves folded and are involved in large overthrust faults. This implies two epi-

sodes of deformation, one before and one after the laying down of these beds. The conglomerates are tentatively correlated with the Fort Union, as that formation is described by Hewett and Lupton in recent papers. These workers also recognize two episodes of disturbance, quite probably the same two noted by the writer. One they place as post-Lance and pre-Fort Union, the other as post-Fort Union and pre-Wasatch. If their correlations are correct they find both episodes of diastrophism to be post-Lance. This appears to be contrary to the idea of Knowlton and others who point very definitely to a pre-Lance (pre-Arapahoe) period of folding. We must conclude, therefore, either that the so-called Lance and Fort Union of the Big Horn Basin, as the terms are used by Hewett and Lupton, are not the equivalents of the Lance and Fort Union described by Knowlton, or else we must conclude that there are three episodes in the orogeny of the Rocky Mountains, one pre-Lance and two post-Lance.

The present status of the Pleistocene in Illinois: MORRIS M. LEIGHTON. Detailed studies on the Pleistocene in Illinois, begun in 1886 under the supervision of Professor T. C. Chamberlin, led to the publication in 1899 of Monograph XXXVIII. on "The Illinois Glacial Lobe," by Mr. Frank Leverett. Aside from certain obscure problems which were left for further study, two important questions have since arisen from changes and shifts in the classification of American drift-sheets. When the verity of the Iowan epoch was questioned, subsequent to the publication of Monograph XXXVIII. the Iowan drift in Illinois was discarded. Since then, the area has been referred to the Illinoian stage, then to a substage of the Illinoian, and still more recently a considerable portion has been suggested as being possibly Early Wisconsin. Whether the drift in northwestern Illinois is wholly or in part Illinoian, Iowan or Early Wisconsin remains to be determined by critical and comparative field-work. The Wisconsin drift deposits were divided into two major drifts in Monograph XXXVIII. but later were reduced to two subordinate stages, and more recently a suspension of the sub-stages "Earlier" and "Later" has been proposed. An early critical study of the drift of northwestern Illinois and of the basis of classification of the Wisconsin drift-sheets is contemplated.

A possible factor in the origin of dolomite: W. A. TARR. It is believed from the study of the areal and time distribution of dolomite that its origin is directly dependent upon shallow continental seas, or lakes, for the necessary concentration of magnesium salts in sufficient amounts for its formation; that the deposition took place upon the sea or lake bottom; that in such seas or lakes we have an adequate source of magnesium; and that such a mode of origin is compatible with the interbedding of dolomite with limestone.

Some glacier studies in Alaska: ROLLIN T. CHAMBERLIN. The ultimate purpose of these studies was to obtain a better understanding of the true nature of glacier motion. Some of the more immediate purposes were to demonstrate movement along definite shear planes which would indicate brittleness and rigidity of materials; and also to determine what relation there might be between the rate of shearing and the temperature, time of day, daily range of temperature, amount of water entering the ice, and variable meteorological conditions. This investigation was undertaken by means of a self-recording clock-work apparatus which was attached to two rods driven into the ice, one above the fracture plane to be investigated and the other below it. The apparatus was sensitive to shearing amounting to as little as one hundredth of an inch. Many difficulties were encountered and only indifferent success achieved. Such records as were obtained seemed to indicate that shearing was more rapid between 6 P.M. and midnight than between 6 A.M. and noon. This would not be at the time of greatest melting but lagging after it. It would be when there was the most water in the ice. A study of the "sloughing off" of Child's Glacier and especially the relation between the shearing planes and the blue bands constituted an important and critical part of the investigation.

The stratigraphy of the Chester series of southern Indiana: CLYDE A. MALOTT AND J. D. THOMPSON, JR. The following is the first attempt to give the entire detailed stratigraphy of the Chester Series of Indiana, using the names adopted by the Kentucky and Illinois surveys and by the writer in a former publication:

BUFFALO WALLOW Formation	Siberia ls. at base, 1–12 feet; overlaid by some 60 feet of sandy sh. and a thin ls.
TAR SPRINGS Formation	Massive ss., 0–75 feet, and sh., 50–125 feet; thin impure limestones in shale when ss. is absent or thin.
GLEN DEAN Limestone	Massive, often oolitic limestone; 10–45 feet.

Hardinsburg Sandstone	Hard, flaggy ss., with some sh. above and below; 25–40 feet.
Golconda Limestone	Bedded to massive ls., often oolitic; contains chert; and frequently thin sh. bands; 0–40 feet.
Indian Springs Shale	20 feet of olive sh. characteristically underlies the Golconda limestone.
Cypress Sandstone	Massive, laminated, friable, yellow ss.; 25–45 feet.
Beech Creek Limestone	Bedded to massive, compact ls.; 8–25 feet.
Elwren Sandstone	Ss. not persistent; the interval often entirely sh.; 15–60 feet. Local unconformity at the base.
Reelsville Limestone	Compact to oolitic, pyritiferous; wethers red; one ledge at north; some sh. at south; 0–12 feet.
Brandy Run Sandstone	Massive to bedded ss.; usually some sh. above and below the ss.; 10–65 feet. Local unconformity at base.
Beaver Bend Limestone	Bedded to massive, cream-colored, usually oolitic ls.; 2–20 feet.
Sample Sandstone	Usually massive and accompanied by sh.; interval frequently all sh.; 10–40 feet.
MITCHELL LIMESTONE GROUP	
Gasper Oolite Limestone	Compact to oolitic ls., 15–40 feet. Lower Gasper of K Major unconformity at base. Bottom of Chester following Weller.
Fredonia Oolite Limestone	Compact, lithographic and white, finely oolitic ls.; 60–80 feet. Major unconformity at base. Bottom of Chester following Ulrich.
St. Louis Limestone	

The correlation of coal seams by means of spore-exines: Reinhardt Thiessen. On microscopic examination of sections of different coal seams it is readily seen that each seam presents certain appearances and certain constituents that are common to all sections from the one seam but which differ in some respects from those in any other seam. The spore-exines in particular have very definite and clearly defined characteristics, such as form, size and sculpturing by means of which different kinds can easily be distinguished from one another. These spore characteristics have been so well preserved in almost all coals that the spores of one species of plants can be clearly distinguished from those of other species. In examining the spore-exines of a number of sections of one seam, it is soon found that by far the larger bulk of the spore-exines of that seam are often very largely of the same kind. In some, two kinds, while in others, three kinds of exines may form the main bulk. In comparing the predominating exines of one seam with those of another it is not difficult to see that those of one bed are different in some way from those of any other. Occasionally there will be found in a given coal seam a spore-exine that differs materially from those found in other seams. This spore-exine is a distinguishing characteristic of the coal seam in question but not in general the predominant one. As is the case in the peat forming bogs of to-day, where each bog or series of bogs contains one, two or three species of plants that predominate, so in the peat bogs of the Coal Age, each bog giving rise to a future coal seam must have contained one, two, or three, sometimes perhaps more, species of plants predominating in that bog and differing from those of bogs of any other time or perhaps locality. There are sufficient grounds for the broad statement that, as far as they have been examined, each coal seam contains one or more kinds of spore-exines that are predominant and characteristic, or if not predominant, are at least characteristic of that seam. By this means any seam may readily and easily be distinguished from any other.

Climate and geology: Stephen S. Visher. It is being increasingly realized that a knowledge of climate is very helpful to geologists. (1) In order to understand differences in weathering, erosion, transportation and deposition, climate and its differences must be understood. (2) Paleoclimatology, or the study of the climates of the geologic past is an important aspect of historical geology. Several very eminent geologists have studied ancient climates and the influence of climate and have enriched the science of geology greatly by so doing. They have urged further study of this by no means exhausted subject. Davis, Barrell, and Huntington have contributed much to an appreciation of the importance of climate in physiography and sedimentation. Schuchert has given the best summary of the climates of geologic time. Cham-

berlin (T. C.) was led by his study of glacial climates to formulate several hypotheses which have done much to advance geology (see "The Origin of the Earth"). The recently published work of Ellsworth Huntington concerning changes of climate is of notable interest to geologists. The data he has accumulated and the stimulating hypotheses he has advanced to interpret these data are worthy of most serious consideration. The importance of climate and the promised fruitfulness of its study has led the speaker to attempt to facilitate its study by summarizing what is known as to climate under the title "Laws of Climate." This summary will be published soon in *The Monthly Weather Review.*

A notable case of successive stream piracy in southern Indiana: CLYDE A. MALOTT. This paper deals with the Knobstone cuesta region lying between the Muscatatook and Ohio Rivers near the eastern margin of the driftless area of southern Indiana. Its purpose is to show specifically the responsibility of the geologic structure and topographic condition in drainage adjustment. Details shown how the particular lithologic units with their regional westward dip are important conditioning factors in giving rise to topographic forms. Other conditioning factors scarcely less important are the so-called time factors, such as various uplifts, rejuvenation and glaciation. The peculiarity of the streams flowing east from the Knobstone escarpment is noted. Blue River with its peculiar unchanging gradient is discussed in some detail, as it is representative of all the streams on the backslope of the cuesta. It is shown that the piracy of the Muddy Fork of Silver Creek has taken place as a result of the geologic structure and topographic condition along the Knobstone cuesta. It is not a single instance of piracy, but consists of successive piracy wherein a large number of tributaries belonging to a single system have been annexed one after another to the drainage system of the invading stream. Some 35 square miles have been stolen. The conditions are highly favorable for piracy to continue, and eventually the largest part of the Muddy Fork of Blue River will be taken over by the Muddy Fork of Silver Creek. Such piracy will continue until a balanced condition of the gradients of the two stream systems is reached. Such a condition will mark the beginning of old age of the stream systems, when stream adjustments are practically complete.

The Satsop formation and structure of the Cascade range: J. HARLEN BRETZ.

Geotectonic economy of thrust-faulting: CHARLES R. KEYES.

ROLLIN T. CHAMBERLIN,
Secretary

THE AMERICAN MATHEMATICAL SOCIETY

THE two hundred and tenth regular meeting of the society was held at Columbia University on Saturday, April 24, extending through the usual morning and afternoon sessions. The total attendance exceeded one hundred and thirty and included eighty-two members. President Frank Morley occupied the chair, yielding it to ex-President R. S. Woodward during the presentation of the papers on relativity at the afternoon session. The Council reported the election of the following persons to membership in the Society: Professor H. S. Everett, Bucknell University; Dr. J. L. Rouse, University of Michigan; Professor Nilos Sakellariou, University of Athens; Mr. H. L. Smith, University of Wisconsin; Professor Eugene Taylor, University of Wisconsin; Professor W. P. Webber, University of Pittsburgh. Thirteen applications for membership were received.

Professor L. P. Eisenhart was reelected to the Editorial Committee of the *Transactions,* for a term of three years. Professor P. F. Smith will retire from the Editorial Committee on October 1, after nine years' service as editor, and Professor G. D. Birkhoff will fill out Professor Smith's unexpired term. Professor Oswald Veblen was appointed a representative of the society in the Division of Physical Sciences of the National Research Council for a term of three years. Professor Veblen's Cambridge Colloquium lectures on Analysis Situs will be published by the society in the fall. Committees were appointed to confer with a committee of the Mathematical Association on joint plans for future meetings and to prepare nominations for officers for the annual election next December.

On the recommendation of the Council it was unanimously voted to incorporate the society under the membership corporations law of the state of New York. The new form of organization will involve hardly any changes beyond those necessary to comply with legal requirements. The board of trustees will be composed of those members of the Council who are elected by the society, the ex-officio members not being eligible as trustees. Otherwise the constitution and by-laws, which have come down from the beginnings of the so-

ciety and which are a highly efficient instrument of government, well worthy of study, will remain practically as they stand.

The committee on reorganization of the society is actively engaged in preparing plans for carrying on the administrative work after the present year and enlarging the society's income. It will make specific recommendations at a later meeting. A report was received from the committee on the International Mathematical Union, and the formation of an American Section of the Union was approved. The report of the committee on bibliography, recommending the establishment of a journal of mathematical abstracts, was approved, and the committee was authorized to take steps toward securing the necessary financial support.

In the interval between the sessions over fifty members and friends took luncheon at the Faculty Club; thirty gathered there at the dinner after the meeting.

The greater part of the afternoon session was devoted to a symposium on Relativity at which the following papers were presented:

1. "The physical and philosophical significance of the principle of relativity," by Professor Leigh Page, of Yale University.

2. "Geometric aspects of the Einstein theory," by Professor L. P. Eisenhart, of Princeton University.

The regular program consisted of the following papers:

N. A. Court: "On a pencil of nodal cubics."

E. L. Post: "Introduction to a general theory of elementary propositions."

E. L. Post: "Determination of all closed systems of truth tables."

Jesse Douglas: "The dual of area and volume."

J. K. Whittemore: "Reciprocity in a problem of relative maxima and minima."

I. A. Barnett: "Linear partial differential equations with a continuous infinitude of variables."

I. A. Barnett: "Functionals invariant under one-parameter continuous groups in the space of continuous functions."

T. R. Hollcroft: "A classification of plane involutions of order four."

Tobias Dantzig: "A group of line-to-line transformations."

A. R. Schweitzer: "On the iterative properties of the abstract field."

J. F. Ritt: "On the conformal mapping of a region into a part of itself."

L. R. Ford: "A theorem relative to rational approximations to irrational complex numbers."

L. E. Dickson: "Recent progress in the theory of numbers."

G. D. Birkhoff: "Note on the ordinary linear differential equation of the second order."

Joseph Lipka: "The motion of a particle on a surface under any positional forces."

Joseph Lipka: "Note on velocity systems in a general curved space of n dimensions."

J. E. Rowe: "Testing the legitimacy of empirical equations by an analytical method."

Oswald Veblen: "Relations between certain matrices used in analysis situs."

O. D. Kellogg: "A simple proof of a closure theorem for orthogonal function sets."

C. L. E. Moore: "Rotation surfaces of constant curvature in a space of four dimensions."

H. S. Vandiver: "On Kummer's memoir of 1857 concerning Fermat's last theorem."

Nilos Sakellariou: "A note on the theory of flexion."

Abstracts of the papers will be published in the secretary's report in the July issue of the society's *Bulletin*.

The Chicago Section held a two-day meeting at Chicago on April 9–10, the program including a symposium on the Maxwell field equations and the theory of relativity. The San Francisco Section met at Stanford University on April 10.

The twenty-seventh summer meeting and ninth colloquium of the society will be held at the University of Chicago during the week of September 6–11. The colloquium will open on Wednesday, and will consist of two courses of five lectures each by Professor G. D. Birkhoff, of Harvard University, on "Dynamical systems," and Professor F. R. Moulton, of the University of Chicago, on "Certain topics in functions of infinitely many variables."

F. N. Cole,
Secretary

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